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BERYLLIUM:
AN ANNOTATED BIBLIOGRAPHY
OCTOBER - DECEMBER 1962
SUPPLEMENT III

SPECIAL BIBLIOGRAPHY
SB-62-22

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Compiled by

JACK B. GOLDMANN

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ABSTRACT

The following annotated bibliography covers publications released during the fourth quarter of 1962. Citations are arranged alphabetically by author under the broad subject headings of Alloys; Analysis; Applications; Bibliographies; Compounds; Corrosion; Fabrication Techniques; Joining; Mineralogy; Oxides; Powder Metallurgy; and Casting; Processing, Properties and Miscellaneous. Reference to the use of beryllium fuels, nuclear reactor applications, effects of radiation, and Cu-Be alloys have been omitted.

The resources of Lockheed Missiles and Space Company Technical Information Center were utilized in the preparation of this bibliography.

Search completed January 1963.

BERYLLIUM

ALLOYS

1. Badaeva, T. A. and R. I. Kuznetsova
Phase diagram of the thorium-beryllium system. INSTITUT METALLURGIA IM A. A. BAIKOVA. TRUDY p.358–368, 1961. (In Russian)

From experimental data, the phase diagram of the Th-Be system was constructed. $ThBe_{13}$ with a face-centered lattice and melting at 1930° was in eutectic equilibrium with a solid solution based on Th (α–Th). The eutectic point (at 38.5 at.% Be) was located at approximately 1240°. $ThBe_{13}$ was also in peritectic equilibrium (peritectic point at 1330°, 0.03 at.% Th) with a solid solution based on Be (α-Be). The solubility of Be in Th in the solid solid state was < 1 at.% at 1150° and practically zero at room temperature; that of Th in Be was < 0.01 at.% at room temperature to 1250°.

2. McDonald, J. C.
Magnesium and beryllium alloys. JOURNAL OF METALS 14:25, Sep 1962.

The properties of the two lowest density structural materials make them particularly desirable in compression members of structures, when failure occurs by buckling in the elastic range. On the other hand, structures critical in tension, such as pressure vessels, can better be made of other materials. Considered in the usual sense, there are no alloys of beryllium commercially available for structural use. This is not true of magnesium, but the two metals are again somewhat similar in that maximum mechanical properties are achieved by control of the working processes rather than by heat treatment. Beryllium is a much newer material than magnesium, cannot be made into as wide a variety of structures, and is much more expensive; but when it can be used it provides a marked weight advantage over the older material.

3. Yemel'Yanov, V. S., Yu. G. Godin and A. I. Yevstyukhin
Preliminary study of alloys of the system zirconium-aluminum-beryllium. In METALLURGY AND METALLOGRAPHY OF PURE METALS, V. S. Yemel'Yanov, and A. I. Yevstyukhin, eds. N. Y., Gordon and Breach, Science Publishers, Inc., p. 55–75, 1962.

Study of alloys of this system by thermal analysis, metallography, x-ray phase analysis and hardness which presents phase diagrams, hardness curves and microstructure of the alloys of six vertical sections: $ZrBe_9$-Zr_4Al_3, $ZrBe_9$-$ZrAl_2$, $ZrBe_2$-$ZrAl_2$, $ZrBe_{13}$-$ZrAl_3$, $ZrBe_{13}$-Al, and $ZrAl_3$-Be.

ANALYSIS

4. Adamovich, L. P. and B. V. Yutsis
Colorimetric determination of beryllium in bronze by aluminon. ZAVODSKAYA LABORATORIIA 28:920–921. (In Russian)

The optical density of beryllium-aluminon (ammonium aurintricaroxylic acid) formed at pH = 4.4 ± 0.05 was determined. Copper was masked by the complexon. The relative order of error is ± 1.52.

5. Amonenko, V. M. et al.
Beryllium "whiskers". FIZIKA METALLOV I METALLOVEDENIE 13(6):928–930, Jun 1962. (In Russian)

The Physicotechnical Institute, Academy of Sciences USSR, has grown beryllium whiskers several tenths of a micron in diameter and several millimeters long by vacuum vapor deposition of 99.9%-pure Be on the inner surface of a cylindrical evaporation column made of molybdenum sheet. An intensive growth of whiskers was observed at an evaporation rate of 0.4 to 0.9 $g/cm^2 \cdot hr$. For an evaporation

temperature of 1515°C the condensation temperature was found to be 870 to 950°C and the condensation rate $\Delta m/\Delta S \quad \Delta r = 0.02 - 0.05$ g/cm^2.hr [see illustration]. X-ray diffraction patterns showed that all specimens were single crystals with the direction of growth along the [221], [331], and [111] axes.

6. Goryushina, V. G.
The present state of the anllytical state of beryllium. In METODY OPREDELENIYA A ANALIZA REDK. ELEMENTOV. Moscow, Publishing House of the Academy of Sciences, 1961. p. 79–107. (In Russian)

Descriptions of methods are given for the determination of beryllium in ores, minerals, ore concentrates, copper, nickel, and niobium alloys, raw materials, and hydrometallurgical products. Sixty-six references are included.

7. Gutmann, V.
THE POLAROGRAPHIC DETERMINATION OF BERYLLIUM. Vienna.Univ. (Austria). Technical note no. 2, 8 June 1962. 3p. (Contract AF 61(052)-487) (ARL 62-391) ASTIA AD-282 391.

The beryllium wave in anhydrous dimethyl sulfoxide was used for the polarographic-analytical determination of beryllium, following its separation by acetylacetone extraction.

8. Henry, W. M
DEVELOPMENT OF ANALYTICAL TECHNIQUES FOR THE DETERMINATION OF MINUTE QUANTITIES OF SELECTED ELEMENTS IN BERYLLIUM. Battelle Memorial Institute, Columbus, Ohio. Interim report no. 1, 6 Jun– 6 Aug 1962. 10 August 1962. 3p. (Contract Nos 62-0629-c) ASTIA AD-283 770.

Information has been obtained on recently produced high-purity beryllium metals Vacuum-distilled beryllium, made from initially high-purity metal, appears to be

one of the most promising sources of material. However, a good evaluation of the quality of the materials is handicapped by a lack of complete analytical data and/or the accuracy of the values presented.

9. O'Connor, D. J. and D. Roman
AN APPARATUS FOR DIFFERENTIAL THERMAL ANALYSIS AND ITS USE IN THE INVESTIGATION OF SOME BERYLLIUM COMPOUNDS. Australia. Atomic Energy Commission Research Establishment, Lucas Heights, New South Wales. Rept AAEC/TM-131. Mar 1962. 14p.

An apparatus for differential thermal analysis of alpha-active or toxic materials is described. The technique is superior to thermogravimetric analysis. Analysis of the dehydration of beryllium sulfate shows that the process takes place in three stages. A modified apparatus for quantitative work is described.

10. Rooksby, H. P. and I. R. Green
The identification and determination of foriegn phases and constituents in metals, with special reference to beryllium. ANALYST 87:539-545, Jul 1962.

The wide scope of analysis required to permit a correlation to be established between the constitution and properties of a metal is discussed. The view is expressed that the state of combination and the manner of distribution of impurities, as well as the amounts present, must be determined. This is shown by reference to analytical work on beryllium; results on several different commercial varieties are reported. Attention is directed to the presence of several impurity phases, including oxide, carbide, nitride, and elemental silicon and aluminium. Two intermetallic compounds were denoted, but are incompletely identified. The value of selective solution methods for isolating some non-metallic constituents is stressed.

11. Taylor, R. E.
A HIGH TEMPERATURE THERMAL CONDUCTIVITY APPARATUS. Atomics International, Division of North American Aviation, Inc., Canoga Park, Calif. Mar 1962. 27p. (Contract AF33(657)-7136) (ASD-TDR-62-348)

A high-temperature, steady-state thermal conductivity apparatus is described. This apparatus was used to measure the conductivity of diverse materials, such as graphite, metals, carbides, oxides, and liquid copper. Measurements were made at 200 to 2500° C. The procedures used, difficulties encountered, limitations, and accuracy are discussed. Results previously obtained with this apparatus on... beryllia... are presented graphically and are compared with other results.

12. Tsyvina, B. S. and M. B. Ogareva
Colorimetric determination of Be with aluminon in niobium base alloys. ZAVODSKAYA LABORATORIIA 28:917–919, 1962. (In Russian)

Colorimetric determination of Be in reaction with aluminon (ammonium aurintricarboxylic acid) in niobium base alloys is suggested by adding tartaric acid for retaining niobium in the solution. Effects of admixtures on Be determination in 100 mg of complexon and 10 ml of niobium tartrate containing 1 mg/ml Nb were also determined.

APPLICATIONS

13. Krusos, J. N. et al.
SHEET BERYLLIUM - COMPOSITE STRUCTURES. Aeronca Mfg. Corp. Middletown, Ohio. Interim technical documentary progress rept. 1 Apr–30 Jun 1962. Jul 1962. 259p. (Contract AF-33(657)7151) (ASD TR 7-845, vol. 3) ASTIA AD-284 842.

The design, manufacturing, testing, and evaluation of reinforced ceramic heat shields combined with load bearing honeycomb panel structure are discussed. The composite structure will be capable of withstanding surface temperatures in excess of 3000° F for one hour. The load bearing semi-monocoque structure will operate

in temperature ranges suitable for beryllia, stainless steels, and super alloys. The predominant development effort is in the application of beryllium to the load bearing structure. A ninety-inch section of a typical lifting body re-entry vehicle will be fabricated for test under a simulated super-orbital re-entry environment. The program was redirected to meet super-orbital mission loads. The design surface temperature of the forebody structure during re-entry is retained at 3400° F, and an ablative coating is contemplated to resist extreme heat rates which occur briefly during the super-orbital re-entry phase. Materials selection for the structural portions include A-286 honeycomb, and A-286 and beryllium facing sheets.

14. Paalman, H. H. and C. J. Pings
Beryllium sample cell for x-ray-diffraction study of liquids. REVIEW OF SCIENTIFIC INSTRUMENTS 33(4):496-497, 1962.

A note. This cylindrical cell made from hot extruded beryllium powder has been tested for internal pressures up to 1000 lb/in^2. Satisfactory diffraction studies have been performed at internal liquid pressures up to 100 lb/in^2 at - 193° C.

BIBLIOGRAPHY

15. Armed Services Technical Information Agency, Arlington, Va.
BERYLLIA - A REPORT BIBLIOGRAPHY.
Report ASTIA ARB No. 10706. Jun 1962. 20p.

A review of literature published between 1957 and June 1962, covering studies made on the hot pressing, analysis, sintering, fabricating and coating of beryllia.

16. Armed Services Technical Information Agency, Arlington, Va.
GRAIN REFINEMENT IN REFRACTORY METALS - A REPORT BIBLIOGRAPHY. Report ASTIA ARB No. 10653. Jun 1962. 17p.

A review of literature published from 1957 to June 1962 covering electron beam melting, arc casting, heat treating, grain refinement, forging and rooling of ... beryllium ... and its alloys.

17. Barriault, R. J. et al.
THERMODYNAMICS OF CERTAIN REFRACTORY COMPOUNDS–VOLUME 2-BIBLIOGRAPHY OF CODED REFERENCES. Avco Corp., Research and Advanced Development Division, Wilmington, Mass. May 1962. 303p. (Contract AF33(616)-7372) (ASD TR 61-260, PART I, Vol. 2)

A theoretical and experimental study over the temperature range from 298.15 to 6000° K was made of the thermodynamics of oxides, borides, carbides and nitrides of the metals in groups IVN, VB, VIB, and VIIB of the Periodical Chart in addition to silicon, boron, scandium, beryllium, magnesium, calcium, strontium, and osmium. Because of its large size, this bibliography has been printed out in working form directly from the IBM cards.

18. Lane, Z. D. et al.
PHYSICAL PROPERTIES AND PHASE DIAGRAMS OF TEN REFRACTORY OXIDES. PART 2. JOURNAL LITERATURE–SELECTED BIBLIOGRAPHY. California Univ., Livermore. Lawrence Radiation Laboratory. Rept. UCRL-6262(Pt. 2) Jul 1962. 85p. (Contract W-7405-eng-48)

The bibliography contains information of the physical properties and phase diagrams of oxides of aluminum, beryllium . . . References were taken from Chemical Abstracts, Ceramic Abstracts, Engineering Index, Nuclear Science Abstracts, Physics Abstracts, and Refractories Bibliography. Arrangement is alphabetical by author.

COMPOUNDS

19. Badaeva, T. A. and R. I. Kuznetsova
Structure of Th-Be alloy. In STROENIE SPLAVOV NEKTORYKH SYSTEM S URANOM I TORIEM. Moscow, Gosatomizdat, 1961. p.358–368. (In Russian)

The constructed thorium-beryllium constitution diagram exhbitis an ffc-lattice $ThBe_{13}$ compound (92.86 at.% Be) with a melting point at ~1930° C. $ThBe_{13}$ compounds

are in eutectic equilibrium with thorium base solid solutions (a_{Th}). The eutectic is found near 38 at. % Be at 1240° C, and the pertectic point is near 0.03 at. % Th at 1330° C. Beryllium solubility in Th at 1150° C is less than 1 at. %; from 1250° C to room temperature it is less than 0.01 at. %.

20. Badaeva, T. A. and R. A. Kuznetsov
Structure of $ThBe_{13}$-UBe_{13} alloys. In
STROENIE SPLAVOV NEKTORYKH SYSTEM
S URANOM I TORIEM. Moscow, Gosatomizdat,
1961. p. 423–427. (In Russian)

Microstructure, x-ray diffraction, and hardness analyses of annealed specimens revealed a continuous series of solid solutions between $ThBe_{13}$-UBe_{13} in the Th-Be-U.

21. Balueva, G. A. and S. I. Ioffe
Organic compounds of beryllium, calcium,
strontium, and barium. USPEKHI KHIMII
31:940–962, Aug 1962. (In Russian)

A review is given of the physical and chemical properties of Be, Ca, Sr, and Ba organic compounds. The electro-positive compound of Ca, Sr, and Ba are similar to Le and Na in their ability to join with ethylene bonds, however, their reactivity is weaker. Beryllium organic compounds are quite similar to magnesium in their covalent structure and relative reactivity.

22. Barriault, R. J. et al.
THERMODYNAMICS OF CERTAIN REFRACTORY
COMPOUNDS–VOLUME 2-BIBLIOGRAPHY OF
CODED REFERENCES. Avco Corp., Research
and Advanced Development Division, Wilmington,
Mass. May 1962. 303p. (Contract AF33 (616)-
7372) (ASD TR 61-260, PART I, Vol. 2)

A theoretical and experimental study over the temperature range from 298.15 to 6000° K was made of the thermodynamics of oxides, borides, carbides and nitrides of the metals in groups IVN, VB, VIB, and VIIB of the Periodical Chart in addition to silicon, boron, scandium, beryllium, magnesium, calcium, strontium, and osmium. Because of its large size, this bibliography has been printed out in working form directly from the IBM cards.

23. Booker, J., R. M. Paine and A. J. Stonehouse
INVESTIGATION OF INTERMETALLIC COMPOUNDS FOR VERY HIGH TEMPERATUREAPPLICATIONS.
Brush Beryllium Co., Cleveland, Ohio. Interim rept. 1, Nov 1960–31 Dec 1961 on Refractory Inorganic Non-metallic Materials. Jul 1962. 82p. (Contract AF 33(616)6540, Proj. 7350) (WADD TR 60-889, Pt. 2) ASTIA AD-284 945.

Three areas were studied in a continuing investigation of intermetallic beryllides and silicides for very high temperature applications. The measured properties of Ta_2Be_{17} were unaffected by minor variations in stoichiometry between 800 and 3000°F. Results are reported for oxidation-rate studies on $TaBe_{12}$, Ta_2Be_{17}, $ZrBe_{13}$, and Zr_2Be_{17} in the temperature range from 2300 to 2750°F. The vapor pressures for these same compounds were measured between 2300 and 2650°F, using the Knudsen cell technique. For $TaBe_{12}$ the activation energy for oxidation is lower than the vaporization energy in this temperature range. The oxidation products of Zr_2Be_{17} were $ZrBe_5$ and BeO. Ternary systems of Be ... with Mo, Nb, Ta, W, or Zr were studied. The promising was a mixed-phase preparation with the stoichiometry of MoBeSi, which exhibited less than 2 mils penetration when oxidized in air at 3000°F for ten hours.

24. Gold coated alumina or beryllia.
FRANKLIN INSTITUTE. JOURNAL 274(2): 160–161. Aug 1962.

Gold coated high alumina or beryllia parts for use in devices requiring a ceramic bond are being offered by Alloys Unlimited, Inc., of Long Island City, N. Y. Made possible by a new technique called the "Gold Kote" process, the new parts can be supplied as flat squares as large as 2 × 6 in. or as disks in diameters as small as 0.050 in. Special shapes such as tubes, notched parts and recessed parts can also be supplied. All parts can be coated with gold on one or both sides in thicknesses ranging from 1/2 to 2 mils according to specifications. The "Gold Kote" can be supplied with a number of different alloy compositions to specific temperature requirements. Using a similar technique, other alloys can also be applied to these ceramic parts with geometric configurations that are favorable. All of these alloys can be appropriately doped p or n type when necessary. Alloys Unlimited's "Gold Kote" parts have been successfully used in TO-18 and TO-5 headers, ceramic modules, and other specialized applications for experimental devices. Sample quantities can be produced for evaluation.

25. Gyunner, E. A.
Physico-chemical analysis of complex-formation in $BeSo_4$-CH_3CONH_2-H_2O system. ZHURNAL NEORGANICHESKOI KHIMII 7:1431-1433. Jun 1962. (In Russian)

A physico-chemical analysis was made of $BeSO_4$-CH_3-$CONH_2$-H_2O. The density index of refraction, viscosity, and electric conductivity indicates the formation of $Be(CH_3CONH_2)_2SO_4$.

26. Perkins, F. C.
INTERMEDIATE-TEMPERATURE OXIDATION OF BERYLLIDES. Denver Research Institute, Denver, Univ., Denver, Colo. Monthly letter rept. no. 11, 1 Jul—1 Aug 1962. 9 Aug 1962. 9p. (Contract AT(11-1)-1092)

Activities in an investigation of the oxidation kinetics and characteristics of $ZrBe_{13}$, Zr_2Be_{17}, $NbBe_{12}$, and Nb_2Be_{17} at 1200 to 1800° F are reported. Results of thermogravimetric experiments with $NbBe_{12}$ and Nb_2Be_{17} in water-saturated Ar are described. The oxidation observed in these experiments was minor, and it was found that Nb_2Be_{17} specimens did not crack during cooling. Oxidation characteristics of Nb_2Be_{17} are discussed. Experimental evicence indicates that a close connection does not exist between precipitate formation and disintegration in these beryllides, and observations suggest that intergranular precipitation is not responsible for disintegration at oxidation temperatures. It is believed that the disintegration phenomena can be explained on the basis of the stresses induced by oxide formation.

27. Perkins, F. C.
INTERMEDIATE-TEMPERATURE OXIDATION OF BERYLLIDES. Denver Research Institute, Denver, Univ., Denver Colo. Monthly letter rept. no. 10, 1 Jun—1 Jul 1962. 8 Jul 1962. 14p. (Contract AT(11-1)-1092)

Continued study of the oxidation kinetics and characteristics of $ZrBe_{13}$, $ZrBe_{17}$, $NbBe_{12}$ and Nb_2Be_{17} at 1200 to 1800° F is reported. Observations of specimen conditions after exposure in water-saturated Ar at 1200, 1400, and 1600° F are included for $ZrBe_{13}$ and Zr_2Be_{17} along with oxidation curves for these tests. Comment concerning the metallography of the samples is included.

28. Perkins, F. C.
INTERMEDIATE-TEMPERATURE OXIDATION OF BERYLLIDES. Denver Research Institute, Denver Univ., Denver, Colo. Monthly Letter Report No. 8, 1 Apr 1962—1 May 1962. 8 May 1962. 12p. (Contract AT(11-1)-1092)

Activities in a program to study oxidation kinetics and characteristics of $ZrBe_{13}$, Zr_2B_{17}, $NbBe_{12}$, and Nb_2Be_{17} at 1200 to 1800° F are reported. Data from gravimetric experiments performed on nominal $ZrBe_{13}$ and Zr_2Be_{17} materials are tabulated. Oxidation curves are included. Effort was also devoted toward investigation of an observed metallographic manifestation which might help explain disintegration phenomena related to beryllide materials. A very fine grain boundary precipitate was detected in nominal $ZrBe_{13}$ and N_2Be_{17} materials after prolonged heat treatment in the intermediate sensitive temperature range. The location of a precipitate found at the junction of the $ZrBe_{13}$ and Zr_2Be_{17} phases may have a higher solubility for a suspected impurity (probably 0) than the other phase. Preliminary metallographic study of nominal Zr_2Be_{17} material which was annealed in the sensitive temperature range revealed no major internal precipitation. This was interpreted to indicate that the Zr_2Be_{17} phase has greater solubility for the impurity. Stoichiometry may therefore have some influence on the mechanism of disintegration in view of the partitioning of the impurity between the two phases.

29. Pogodilova, E. G., A. I. Grigor'ev and A. V. Novoselova
Reactions of beryllium acetate complex compounds $[Be_4O(CH_3COO)_6 \cdot 3R\text{-}NH_2]$ with alcohols. ZHURNAL NEORGANICHESKOI KHIMII 7:1285—1288. Jun 1962. (In Russian)

The products of $Be_4O(CH_3COO)_6 \cdot 3R\text{-}NH_2$ reactions with methanol and ethanol, when boiled over potassium oxides or over metallic magnesium, were analyzed and tabulated. The general scheme of beryllium oxyacetate in alocohols did not confirm the existence of the hypothetical soluble product $Be(OH)OCOCH_3$. It is surmised that at the beginning of the reaction 4 moles of $Be(OR)OCOCH_3$ and one mole of water form $Be_4O(CH_3COO)_6 + 4ROH = 4Be(OR)OCOCH_3 + H_2O$. After continuous heating the water partially hydrolyzes beryllium alcohol acetate.

30. Sulaimankulov, K.
Isotherm of beryllium sulfate-urea-water system solubility, viscosity and gravity. ZHURNAL NEORGANICHSSKOI KHIMII 7:1418–1420. Jun 1962. (In Russian)

The isotherm of solubility, specific gravity, viscosity, and internal friction of $BeSO_4$-$CO(NH_2)_2$-H_2O was studied at 30° C. Two chemical compounds $BeSO_4 \cdot 2CO(NH_2)_2 \cdot H_2O$ and $BeSO_4 \cdot 3CO(NH_2)_2$ were observed and their solubility analysed.

31. Tanaka, K., H. Hashimoto and M. Mannami
Theory and observation of diffraction contrast of electro-micrographs of dislocation and G.P. zone. In PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON MAGNETISM AND CRYSTALLOGRAPHY. PT. 2. ELECTRON AND NEUTRON DIFFRACTION. Tokyo, Physical Society of Japan, March 1962. p. 166–169.

A derivation of an approximate expression for the dynamic scattering of electrons of imperfect crystals is applied to determining elastic lattic distortion around the G. P. zone in Cu-Be alloy. (Beryllium boride)

32. Thompson, C.J., G.C. Sinke and D.R. Stull
Heat of formation of beryllium chloride. JOURNAL OF CHEMICAL AND ENGINEERING DATA 7: 380–381. July 1962.

The heats of solution of Be metal and $BeCl_2$ in HCl solution were measured to be -89.62 and -45.92 kcal/mole fpr (8.381 HCl + 67.982 H_2O), respectively. From these values, the heat of formation for $BeCl_2$ was calculated to be -118.25 ± 0.50 kcal/mole which agrees with the value measured by direct reaction of Be and Cl_2 (-188.03 ± 0.56 kcal/mole).

33. Adams, R.B., G.H. Price and W.I. Stuart
REACTIONS OF PREOXIDISED BERYLLIUM POWDER IN MOIST CARBON DIOXIDE. Australia. Atomic Energy Commission Research Establishment, Lucas Heights, New South Wales. Report AAEC/E-88. June 1962. 13p.

Breakaway corrosion of beryllium in moist carbon dioxide can be avoided if the beryllium is fabricated using preoxidized powder. The powder is preoxidized by heating in dry O_2. Preoxidation of beryllium powder was measured as a function of temperature and time of heating in O_2. The subsequent reactions of the preoxidized powder in moist carbon dioxide at 700° C were studied and the effect of increasing amounts of added oxide was measured. A model is proposed to explain the inhibition of corrosion by added oxide.

34. Aitken, E.A. and J.P. Smith
Oxidation of beryllium intermetallic compounds in moist atmospheres. JOURNAL OF NUCLEAR MATERIALS, 6:119. May-June 1962.

It was found that intermetallic compounds of beryllium undergo attack by moisture in an intermediate temperature range. These intermetallic compounds react with moisture-containing atmospheres at a relatively high rate at 1000 to 1800° F.

35. Fujino, S.
Effects of beryllium on the oxidation of A1-10% Mg molten alloy. NAGOYA KŌGYŌ GIJUTSU HŌKOKU 11(7):397−401. July 1962. (In Japanese)

The influence of beryllium concentration on the oxidation of A1-10% Mg molten alloy is investigated by weight gain measurements using a thermo-balance test at 580-825° C.

36. Pemsler, J.P., D.S. Kneppel and R.G. Jenkins
BERYLLIUM CORROSION. Nuclear Metals, Inc., Concord, Mass. Quarterly report to United States Atomic Energy Commission for the period of 25 April 1962 to 25 July 1962. Report NMI-1903. 31 Aug 1962. 29p. (Contract AT(30-1)-3012) (Work performed under United States-Euratom Joint Research and Development Program)

Investigations were made on factors influencing the corrosion of beryllium in high temperature water and steam. It was found that surface preparation appeared to have a significant effect on the corrosion behavior of beryllium. Etching of beryllium samples fabricated directly from powder resulted in increased attack. Cut samples showed a damaged surface layer which, unless removed by polishing, resulted in increased corrosion attack. It is judged that removal of 12 to 14 mils should be adequate. The results indicate that only materials fabricated directly from powder show significant corrosion resistance. Increasing the purity of beryllium resulted in decreased corrosion resistance. Coarse grained distilled and single crystal zone refined specimens underwent rapid catastrophic corrosion in water at 650°F. An apparatus was constructed to produce dilute alloys from high purity beryllium. Samples are melted in a BeO crucible, bottom poured and cast into a BeO mold. Three castings have been produced.

37. Vachon, L. J.
Protection of beryllium metal by anodic films.
JOURNAL OF NUCLEAR MATERIALS
6:139–141. May–June 1962.

A preliminary study was undertaken to find a means to prevent or retard beryllium interactions with UO_2 and corrosion by CO_2. It was found that a beryllium wafer anodized to form a thin film covering of BeO did not interact with Uranium and offered good corrosion resistance to CO_2.

38. Bennett, W. D.
ANNUAL REPORT ON BERYLLIUM RESEARCH, 1961. Canadian Westinghouse Co., Ltd. Research and Development Laboratories, Hamilton, Ontario. Report CW-R&DL-24. February 1962. 66p. (AECL-1555)

Studies were conducted on the high temperature mechanical properties of hot- and warm-extruded beryllium rods. The warm-extruded rod showed greater susceptibility to heat treatment. Joining methods studied were brazing, electron beam welding, fusion welding by argon arc and pressure welding. Fusion welding by argon arc and pressure welding gave the most satisfactory results for end-cap welding on beryllium tubes and were adopted in the fabrication of burst test specimens. Tube evaluation on any scale was confined to Pechiney hot-extruded tubing and Brush warm-estruded tubing. Burst tests on the Pechiney material gave scattered results attributed to micro-cracks and chloride inclusions. Warm-extruded tubing gave consistently reproducible results representing high hoop stresses. It was shown by x-ray diffraction studies that certain compounds could be either precipitated or retained in solution by suitable heat treatments. The changes in mechanical properties with heat treatment were presumed to be due to the degree of precipitation which had occurred.

39. Bucher, R. F.
AN INVESTIGATION OF ELECTRICAL DISCHARGE MACHINING AS APPLIED TO CORE DRILLING BERYLLIDES. General Electric Co. Aircraft Nuclear Propulsion Department, Cincinnati, Ohio. Report DC-60-3-173. March 1960. 37p. (Contract AT(11-1)-171)

Applicability of the electrical discharge machining process to core drilling zirconium beryllide ($ZrBe_{13}$) and niobim beryllide ($NoBe_{12}$) was investigated. Test series were designed to investigate the effects of the following variables on the machinability and physical characteristics of the beryllides; electrode material; current densities; electrode design; servomechanism feed rates; electrode dielectric pressures; and proximity of ground location. The process is one of three which are currently under evaluation to determine their relative applicability to the machining of beryllides. The processes under study are: electrolytic machining; diamond grinding and core drilling; and electrical discharge machining. Comparison of the free machining rates

for beryllides with published removal rate for standard materials under similar conditions is presented. This relative comparison indicated superior removal rates for the beryllides when the electrical discharge machining process was employed. Cutting rates of 0.70 in./min for zirconium beryllide and 0.31 in./min for niobium beryllide were obtained utilizing a 0.250-OD electrode. Further decreases in cutting timer per hole were anticipated through changes in electrode design, and application of gang drilling. Billet and core fracture presented a significant problem in the machining of zirconium beryllide. The incidence of this fracture, however, was lower than was observed in diamond core drilling, where pressure is exerted between the tool and work-piece. Two-to-three minutes perinch of cut must be added to the cutting time listed for zirconium beryllide; to allow for removal of pieces of fractured core, which cause interruption of cut. Effort is currently being directed in the department toward improving the ductility of zirconium beryllide. Billet and core fracture was not experienced in the tests which were run on niobium beryllide. Machinability studies were not concluded on the other two processes under study, but there was limited diamond core drilling accomplished. A comparison of the two partially developed processes indicates cutting rates-two-to-three times faster when the electrical discharge machining process is employed. One metallographic report was received and no adverse effects from the process were noted; consideration should be given to the limited nature of this data however. The positive results of this investigation lead to the recommendation that continued effort, commensurate with the overall beryllide program, be directed toward the further development of the electrical discharge process for machining beryllides.

40. Calderwood, F.W., D.R. Wilder and H. A. Wilhelm
The jolt-pack fabrication of special ceramic ware.
IOWA ACADEMY OF SCIENCE. PROCEEDINGS
68:202-221. 1961.

The jolt-pack method for fabrication of refractory crucibles and other shapes is described. The particle size distribution of the material to be packed was found to be an important consideration in this method. Data are presented on packing densities of various graded fractions of beryllia and the development of a dense-packing mixture is described.

41. Cooperstein, R.
SINTERABILITY STUDIES OF BeO COMPACTS.
California. Univ., Livermore. Lawrence
Radiation Laboratory. Report UCRL-6725. 28
June 1962. 31p. (Contract W-7405-eng-48)

Work was carried out to determine the optimum sintering conditions for cold-pressed BeO bodies from specific commercial lots of beryllia powder. The effects of 0.1 to

0.5 wt.% additions of specific oxides on the sinterability of beryllia powders were also studied. Results indicated that high-density bodies can be fabricated from pure sulfate-derived beryllia using a cold pressing and sintering technique. Maximum densification was obtained by sintering the bodies in a hydrogen atmosphere at temperatures between 1500 and 1700°C. The effectiveness of low concentrations of minor impurities in promoting the sintering of BeO was demonstrated. Firings with most oxide additions resulted in bodies having higher densities than the pure powders.

42. Gross, A.G., Jr. and R.G. O'Rourke
DEVELOPMENT OF FINE DIAMETER HIGH-PURITY WIRE FROM ZONE-REFINED BERYLLIUM. Brush Beryllium Co., Cleveland, Ohio. Progress report no. 1, 1 Apr–31 May 62. Technical report no. 263–236. 31 May 1962. 30p. (Contract NOw 62-0067-c) ASTIA AD-282 720.

Single crystals of zone-refine Be were jacketed in mild steel tubing and were swaged at 450°C. Various intermediate anneals were employed. When the Be had been reduced to the desired diameter, swaging was stripped and the jacket was removed. The high-purity Be wire was then deformed by standard Be wire-drawing techniques. Extensive longitudinal rupturing occurred during this operation and very poor yields were experienced. Even so, a fair amount of fabrication experience was gained and some important metallugrical information was generated.

43. Hayes, A. F. and J. A. Yoblin
BERYLLIUM FORGING PROGRAM. Ladish Co., Cudahy, Wisc. Final Technical Engineering Report, 6 May 1958–19 November 1961. June 1962. 305p. (Contract AF33(600)-36795) (ASD-TR-62-7-647)

Unclad vacuum hot pressed beryllium was successfully forged in closed dies to provide an improved aerospace quality structural material for Air Force requirements. The expendable, hot steel support technique was successfully used to drastically deform unclad beryllium in trial production runs. A mild amount of unrestrained deformation can be imposed on billets of relatively small size. Forged beryllium shows a significant increase in mechanical properties over those reported for hot-pressed beryllium. Three of six shapes investigated were successfully and reproducibly completed after adequate development of tooling and forging sequences for each

specific shape. The production runs for the initial forging operations of the other three shapes were also successful; however, ring rolling and forming, techniques were only partially successful. A comprehensive mechanical properties evaluation, including tensile, compression, shear, fatigue, creep rupture, and impact tests, demonstrated that significantly improved properties in the plane or direction of metal flow can be achieved through forging. Transverse tensile properties were lower than longitudinal properties with the difference being dependent upon the amount of work. Development of the forging process for beryllium was based upon results of an investigation of forging variables. A series of 144 beryllium samples, comprising both hot-pressed and arc-cast types of beryllium, were encased in 1/2-inch thick steel jackets and upset forged to determine a preferred material, method of deformation (press or hammer), and forging temperature. Press forging hot-pressed beryllium at a temperature of 1375°F produced the highest quality forgings from the standpoint of soundness and mechanical properties.

44. Krusos, J.N. et al
TWO-YEAR EFFORT IN THE DEVELOPMENT OF BERYLLIUM FACED SANDWICH STRUCTURES. American Society for Testing and Materials, Philadelphia, Pa. ASTM paper-83. 1962. 33p. (Presented at the Fourth Pacific Area National Meeting of ASTM, Los Angeles, Oct. 1–5, 1962) NASA N62-17729.

Beryllium fabrication techniques have been developed for the construction of beryllium-faced sandwich structures. These techniques, designed to overcome the extreme brittleness and high notch sensitivity of beryllium, consist of machining, chemical milling, forming and brazing. Tests of yield strength and ultimate tensile strength on specimens fabricated by these methods gave the following results: (1) machining damage to the edge of the specimen to detrimental to the tensile properties; (2) careful edge preparation is necessary to obtain tensile properties; (3) annealing does not completely remove the effect of edge damage: (4) silver braze alloy appears to decrease the tensile properties only slightly.

45. Moyer, K.H. and I. Sheinhartz
FEASIBILITY STUDY FOR DIRECT ROLLING OF BERYLLIUM POWDERS. Sylvania-Corning Nuclear Corp., Bayside, N.Y. Final Report Covering Period From 15 April 1959 to 30 November 1959. Report SCNC-305. January 1960. 42p. (Contract NORD-17017)

The feasibility of making beryllium sheet by direct rolling of beryllium powder was demonstrated. A green strip was formed by passing beryllium powder through a rolling mill. The green strip was subsequently sintered in argon or vacuum, rerolled, and annealed to form a fully dense beryllium sheet. Properties of the material made by sintering in an argon atmosphere were essentially the same as though of the vacuum sintered material; however, in the former material, there was considerably less loss of material due to vaporization. The finished sheet had a tensile strength of approximately 49000 psi and an elongation of 0.2%. It is believed that the low ductility was mainly due to the thinness of the sheet. The maximum finished thickness was 0.008 in. X-ray diffraction tests indicated that the final sheet had a random structure.

46. Munro, W. and N.A. Hill
The deformation of beryllium under complex stressing. METALLURGIA 66 (395): 105–110. Sep 1962

The results of hot and cold bend tests on beryllium sheet and of deformation of beryllium tubes by the application of internal and external pressure, show that under complex stressing beryllium can show considerable ductility at elevated temperatures. There is a large scatter in tube properties at 620°C., the diametral expansions ranging from 0.2% to 11% and times to failure from 1 minute to 220 minutes under a pressure of 1,000 lb/sq. in. The scatter within each tube is less than the overall scatter, but is great enough to mask any differences between tubes produced by various fabrication techniques.

47. Murphy, E.A. and J.G. Klein
HELICAL FINNED TUBE DEVELOPMENT,
Brush Beryllium Co., Cleveland, Ohio.
February 19–March 17, 1962. 10p. (Contract
AT(40-1)-2912)

Progress is reported on the development of a fabrication technique that will produce high-quality finned beryllium tubing which has resistance to brittle failure under circumferential stress. Results of warm extrusion and warm drawing are presented.

48. Randall, R.N. and F.M. Yans
DEVELOPMENT OF TECHNIQUES FOR THE
EXTRUSION OF BERYLLIUM TUBING. Nuclear
Metals, Inc., Concord, Mass. Report NMI-2602.
30 June 1960. 20p. (Contract AT(30-1)-1565)

Three sizes of tubing were produced: 0.40 × 0.03; 0.75 × 0.03, and 0.75 in. OD × 0.10 in. wall. Two methods of extrusion were used. In one, the filled billet method, the hollow beryllium core in the extrusion billet was filled with a steel filler that was removed after extrusion. In the other method, a hardened steel mandrel was used to form and control the ID of the tube. Extrusion billets were prepared from the starting material, Brush--200 mesh QMV powder, in three ways: powder was packed cold into the extrusion billet can; powder was packed cold into a can, pre-extruded, and machined into extrusion billet cores; and powder was packed cold into a can, hot compated, and machined into extrusion billet cores. The latter method was used for most of the extrusions. The production of the small-size tubing, 0.4 in. OD × 0.03 in. wall, was studied the most extensively.

49. Westlund, E.F.
VACUUM FURNACE BRAZING OF BERYLLIUM.
California Univ., Livermore, Lawrence Radiation
Laboratory. UCRL-6391. Mar 1961. 18p.
(Contract W-7405-eng-48)

Vacuum brazing techniques were developed for joining beryllium to titanium, stainless steel and to itself using silver as the filler. Shear strengths of about 20,000 psi were obtained for all three types of brazes. When brazing beryllium to titanium or to stainless steel, excessive brazing temperature or holding times result in low-strength brazes. Both brazes can be made at temperature as low as 900°C which is 60°

below the melting point of pure silver. Initially, difficulty was experienced in obtaining consistently good brazes when joining beryllium to itself due to poor wetting by the solver. This was overcome by adding a small amount of titanium hydride to the beryllium contact surface. High strength brazes were consistently produced at temperatures from 960 to 1070° C showing that overheating was not a problem.

JOINING

50. Hess, W. T., et al
Fusion welding of beryllium in a vacuum atmosphere. In 1961 TRANSACTIONS OF THE EIGHTH NATIONAL VACUUM SYMPOSIUM COMBINED WITH THE SECOND INTERNATIONAL CONGRESS ON VACUUM SCIENCE AND TECHNOLOGY, OCTOBER 16, 17, 18, 19, 1961, WASHINGTON, D.C. VOLUME 2. L. E. Preuss, ed. Oxford, England, Pergamon, 1962. p. 679–684.

Both hot-rolled and pressed-and-sintered beryllium were successfully fusion welded utilizing an electron beam as a heating source. It was found that with proper heat input and operating pressure conditions, leak tight beryllium weldments having sufficient tensile strengths in the fusion, heat-affected to match the baseplate zones could be accomplished. Thus, vaporization and thermal cracking limits for an operating vacuum and power input could be defined for a particular specimen and quench block geometry. Repair welding of cracks or voids was not found possible for specimens exposed to air prior to repair welding attempts, presumably because of air entrapment within the crevices.

51. Maloof, S. R. and J. B. Cohen
Brazing of beryllium. (Löten von Beryllium) SCHWEISSEN UND SCHNEIDEN 14(3): 113. March 1962. (In German)

Liquid silver spreads only partially on beryllium apparently because of the liquid's rapid intergranular penetration; with silver spreading is better in argon atmosphere than in vacuum; effective joint thickness is quite large with Ag and BeAg alloy as braze material. Butt joint strengths with these two materials are about 60% that of the base metal at room temperature and 80% at 700 to 1450° F.

52. Reed, E. L.
YTTRIUM AND BERYLLIUM END PLUG BONDING.
Atomics International. Division of North American Aviation, Inc., Canoga Park, Calif. Report NAA-SR-Memo-7283. 5 April 1962. 24p. (Contract AT-11-1-GEN-8)

The feasibility of diffusion bonding beryllium end plugs to beryllium tubing was demonstrated. Excellent bonds were accomplished after one hour at 1000°C in vacuum by using a molybdenum restraining die to develop the necessary pressure for diffusion. This process appears to be applicable to scale-up for end closure diffusion bonding of quantity batches of beryllium tubing by using a multiple ability molybdenum restraining die. Inert-gas-shielded welding of beryllium tube and end plug assemblies was unreliable. even when attempted in an atmosphere welding glove box with a dew point of less than minus 60° F. It was possible to effect helium leak tight end closures occasionally by precise one-pass welds in the atmosphere glove box, but multiple pass welds were invariably poor quality.

MINERALOGY

53. Dyad'kina, L. Ya.
Formation of beryl in pegmatite dices. (Osobennosti formirovaniya berilla v pegmatitovykh zhilakh) VSESOYUZNOE MINERLAOGICHESKOE OBSHCHESTVO. ZAPISKI 2ND SER. PT. 92(2):214-219. 1962. (In Russian)

Deposit is located in Central Asia within belt of metamorphic rocks; process of crystal growth in solid medium and its dependence on direction of flow of mineralizing solution; factors contribution to formation of lamellar and platy crystals of beryl.

54. Evans, E. L. and R. A. Dujardin
Unique beryllium depost in vicinity of Ten Mile Lake, Seal Lake area, Labrador. GEOLOGICAL ASSOCIATION OF CANADA. PROCEEDINGS 13:45-51. Dec. 1961.

Barylite and eudidymite, occur throughout radioactive horizon of soda-rich paragneiss which is associated with syenitic intrusives within Letitia group volcanics; beryllium

ineralization occurs also in heterogeneous migmatite and metasomatized shear zones; average grade of paragneiss zones is in range 0.35–0.40% BeO and preliminary drilling has shown continuation to vertical depth of at least 200-ft.

55. Gangloff, A.

Beryllium ores. Actual characteristics and conditions for increasing the supply. BULLETIN D'INFORMATION SCIENTIFIQUE ET TECHNIQUE (Paris) No. 59:64–70. March 1962. (In French)

Up until the last few years, beryl, the principal ore of Be, was produced on a small scale from pegmatite deposits. The development of new applications of Be raises the need to discover new reserves of this metal. This can be achieved by conentrating on the search for low-concentration deposits, but with a more regular and greater tonnage than the pegmatite deposits new exploited. To find these deposits, prospecting methods must he adapted, particularly the use of special detectors. The commercial exploitation of these deposits requires the development of new concentration methods and the adaptation and improvement of present chemical treatment processes.

56. Heinrich, E.W.

Geochemical prospecting for beryl and columbite. ECONOMIC GEOLOGY 57(4):616–619. June-July 1962.

Analysis of Black Hills pegmatites indicates that muscovites from pegmatites relatively rich in beryl and niobium minerals will contain appreciably higher concentrations of these elements than do those muscovites from pegmatites that do not contain discrete niobium or beryllium minerals; this relationship may be used in prospecting for beryllium (and columbium) in pegmatites.

57. Jedwab, J.

Coal as a source of beryllium. SOCIÉTÉ BELGE DE GEOLOGIE DE PALEONTOLOGIE ET D'HYDROLOGIE. BULLETIN 69:67–77. 1960. (In French)

A summary is given of the most important works on coal as a possible source of beryllium. The fifteen references cited show the existence of coals with important beryllium concentrations. The possibility of the eventual utilization of coal ash as a beryllium ore is indicated.

58. Jedwab, J.

Presence of beryllium in certain Belgian coals.

SOCIETE BELGE DE GEOLOGIE DE PALEONTOLOGIE ET D'HYDROLOGIE. BULLETIN 69:77–82. 1960.

(In French)

A study of spectrograms of many Belgian coals shows the existence of beryllium. The data tabulation does not attempt to give a precise quantitative evaluation, but it does permit some conclusions to be drawn. Strata rich in beryllium are rare, and the coeals which are richest in beryllium have the lowest ash content. Beryllium is rarely absent from any of the coals.

59. Kalenov, A.D.

Hydrothermal helvite mineralization in quartz veins. (O gidrotermal'noi gel'vinovoi mineralizatsii v kvartsevykh zhilakh) GEOLOGIYA RUDNYKH MESTOROZHDENII (3):73–79. May-June 1962. (In Russian)

One type of quartz vein consists of quartz, feldspars, and fluorspar; second type contains topaz, wolframite, native bismuth, and sulfides; helvite is deposited in quartz veins at moment of strong decrease in concentration of alumina in mineralizing solutions; composition of helvite group minerals depends on concentration of iron, magnesium and zinc solutions and order in which minerals containing these elements are crystallized.

60. Montoya, J.W. , R. Havens and D.W. Bridges

BERYLLIUM-BEARING TUFF FROM SPOR MOUNTAIN, UTAH; ITS CHEMICAL, MINERALOGICAL AND PHYSICAL PROPERTIES. Bureau of Mines. Report of Investigations No. 6084. 1962. 15p.

Two beryllium-bearing minerals, hydrated form of bertrandite and berylliferous saponite were present in tuff; possibility of separating beryllium minerals from tuff by physical methods appears remote; beryllium mineralization in region occurs in rhyolitic tuff usually overlaid by unaltered rhyolite; beryllium is distributed erratically through tuff in individual mineralized bodies; tuff contains from 0.2 to 18% BeO.

61. Schaller, W. T., R. E. Stevens and Jahns, R. H.
Unusual beryl from Arizona. AMERICAN
MINERALOGIST 47 (5): 672-699. 1962.

A bluish beryl from a pegmatite dike in Mohave County, Arizona, differs distincly from other known beryl in physical properties and chemical composition. The highest measure value of ω for this beryl is 1.610, and the analyzed sample has ω = 1.608, ξ = 1.599. Only four published analyses of beryls with an ω index higher than 1.592 are known, and the highest index heretofore recorded for any beryl, recognized as such, is 1.602. G = 2.92.1 Incomposition, this mineral differs markedly from other beryl. It has the lowest percentage of SiO_2 and of Al_2O_3 of any known beryl. It contains 4.69 per cent of oxides of bivalent elements other than beryllium, chiefly ferrous iron and megnesium. Its content of Cs_2O, 6.68 per cent, is much greater than that of nearly all other known beryl. On the other hand, its content of Li_2O, 0.23 per cent, is only about one-tenth of what would be expected for an alkali-rich beryl. The composition and physical properties are incompatible with distinctive compositional trends determined for beryls by Schaller and Stevens. In general the ω index of alkali beryls are close to the composition indicatcd by the standard beryl formula $Be_3Al_2 \cdot Si_6O_{18}$. The high-index-beryls can be interpreted in terms of the standard beryl formula combined with the sodium-lithium beryl formula $Na \cdot Be_2Al \cdot AlLi \cdot Si_6O_{18}$ and its cesium-lithium analogue. In various solid solutions of these end-members the atomic ratios of Si and Al do not vary, but increases in Li are accompanied by equal increases in Na or Cs and by equal decreases in Be. In contrast to the compositional trends for most beryls, the Arizona beryl is deficient in Al; it is high in Na and Cs but low in Li, and its Be content is abnormally high for a high-index, high-alkali beryl. These relationships are attribedted to the presence of anotherend-member represented by the generalized formula $(Na, Cs) \cdot Be_3 \cdot Al(Fe^{2+}, Mg) \cdot Si_6O_{18}$. The Arizona beryl contains more than 50 per cent of this femag end-member. Most of the Arizona beryl with the highest indices of refraction occurs in the fine-grained border zone of an irregular pegmatite dike, where it typically forms small podlike masses. Each mass is a single skeletal crystal of beryl that contains numerous inclusions of quartz, microcline, albite, fluorite and sphene. More euhedral and prismatic crystals of beryl, considerably less crowded with inclusions, in the inner parts of the dike also have high indices of refraction and usual chemical composition. The composition seems to be direct reflection of a relatively high iron and magnesium content of the pegmatite fluid during its crystallization. These elements probably were derived in large part from digestion of mafic country rock. The incorporation of bivalent iron and magnesium into the beryl structure, in place of some trivalent aluminum, probably resulted in the strong attraction of large monovalent cations, chiefly Cs^+ and Na^+, into the tubular channels of the structure during formation of the crystals.

62. Caillat, R. et al
PROCESS FOR OBTAINING FRITTED BERYLLIUM OXIDE. (Assigned to Commissariat à l'Energie Atomique) Swiss Patent 348,397. 31 Aug 1960.

Beryllium hydroxide, the greater part of which is in the beta form, is calcined and characterized in that a mineral acid or a beryllium salt of the acid is added to the hydroxise or to the oxide which results from the calcination is such a way that the calcined product contains at least 1% mineral acid ions. The acid or salt is chosen so that the ions are eliminated during the subsequent fritting without leaving as solid residue, and the final product is fritted.

63. Coble, O. V., W. A. Taebel and J. W. Sausville
Emission Spectrographic impurity analysis of dense beryllium oxide. In ANALYTICAL CHEMISTRY IN NUCLEAR REACTOR TECHNOLOGY. FIFTH CONFERENCE, GATLINBURG, TENNESSEE, 10–12 OCTOBER 1961. 1961. p. 135–141.

A study was initiated to evaluate mechanical grinding vs acid dissolution of hot-pressed BeO as methods for sample preparation for spectrographic analysis. The former method appeared more favorable with respect to the time element and sensitivity, and further study was undertaken to devise a rapid method of grinding or powdering hot-pressed BeO without introducing contaminants. For initial testing, a mixer/mill with tungsten carbide grinding vial, caps, and ball-pestles was utilized. Resultant introduction of W and Co contaminants caused an unfavorable "matrix effect" and also precluded analyzing for Co. A series of experiments were performed in which plastics were used for the vial and as inserts for the tungsten carbide caps. It was discovered that two pieces of hot-pressed BeO act as ball-pestles and grind each other to powder with the shaking action of the mixer/mill. Consequently, tungsten carbide ball-pestles of impurities found in "raw" BeO powder with impurities found in the same material after it was hot pressed and powdered in an all-plastic grinding system showed remarkable agreement. Sieve materials of various types were used for screening powdered hot-pressed BeO. The results obtained thereby are discussed.

64. Crossley, F.A. and R.J. Van Thyne
DEVELOPMENT OF DUCTILE BERYLLIUM COMPOSITES. Armour Research Foundation, Chicago, Ill. Final Report, 23 December 1960 – 22 December 1961. Report ARF-2212-6. 1 Feb 1962. 29p. (Contract NOw-61-0370-c) ASTIA AD-273 287.

An effort to produce ductile beryllium composites by liquid-phase sintering is reported. Ductility in a predominantly beryllium composite was sought through the attainment of a structure in which beryllium particles are enveloped in a ductile metallic matrix. As the result of the investigation of Al-Ag binary alloys, Al-40 to 50% Ag compositions were added to the Ag-5 to 8% Al compositions as candidate matrices satisfying the requirement that the flow stress of the matrix be matched to that of the principal phase. Composites produced for final evaluation contained defects originating from the processing schedule. The feasibility of applying liquid-phase sintering to produce beryllium composites was established. However, to obtain a fair evaluation of the question of ductility improvement, it is necessary to develop compacting and sintering procedures which will yield sound material for mechanical testing.

65. Durig, J.R., R.C. Lord and L.H. Johnston
Infrared transmittance and reflectance of beryllium oxide. OPTICAL SOCIETY OF AMERICA. JOURNAL 52:1078. Sept. 1962.

The infrared transmittance of BeO single crystals and pressed plates was measured at 50 to 4000 cm^{-1}. The main absorption band fell in the neighborhood of 500 to 1000 cm^{-1}, with three small bands on the high frequency side. The infrared reflectance of BeO pressed disk was measured at 450 to 1200 cm^{-1}; the main reststrahlen frequency was found to be 730 ± 10^{-1} with a subsidiary maximum at 1050 cm^{-1}.

66. Guzman, I. Ya. and D.N. Poluboyarinov
BeO-porous ceramics. OGNEUPORY (10):457-462. 1962. (In Russian)

The porosity (P) , gas permeability, compressive strength, deformation under load, thermal-fatigue resistance, contraction, and heat conductivity of BeO-based light weight porous ceramics have been determined at the Moscow Institute of Chemical Technology imeni D. I. Mendeleyev. Test specimens of varying P were prepared by (1) mixing a suspension of pure BeO, prefired at 1400 or 1600°C and finely divided,

with varying quantities of rosin-size foam, or (2), compacting BeO-based light-wight porous material (filler), fired and crushed with 0 to 40% petroleum coke. In both cases the specimens were dried and dired at 1750° C for 2 hrs. A cellular structure with spherical pores surrounded by a homogeneous crystalline shell was obtained in specimens prepared by (1), while specimens prepared by (2) had a heterogeneous microstructure. In the 31 to 63% P range specimens prepared by (1) retained some compressive strength at temperatures ≤ 1500° C, and deformation set in at ~ 1600° C under a load 8 times the numerical value of density in g/cm^3. In the 30 to 80% P range the thermal-fatigue resistance at temperatures ≤ 1000° C was >40 thermal cycles, owing to high heat conductivity. Contraction after four hours at 1750° C did not exceed 0.5 to 1%. Gas permeability rose and compressive strength declined with increasing P. Petroleum coke-based products were found inferior to foam-based products in mechanical properties. Higher heat conductivity, temperature at the beginning of deformation, thermal fatigue resistance, and favorable nuclear properties make BeO-based porous light weight materials superior to such materials based on other pure oxides.

67. Kahn, J.S. and W. Wadleigh
Preliminary observations on the sintering of BeO.
In ELECTRON MICROSCOPY; FIFTH INTERNATIONAL CONGRESS FOR ELECTRON MICROSCOPY HELD IN PHILADELPHIA, PENNSYLVANIA, AUGUST 29TH TO SEPTEMBER 5TH 1962. VOLUME 1. NON-BIOLOGY. S. S. Breese, ed. New York, Academic Press, 1962. p.H-4.

Powdered BeO was mixed with a lubricant and extruded under pressure through a die. After extrusion the lubricant was burned out of the tube. Observations on the growth of BeO after sintering at 1500° C and 1600° C are described. It is suggested that at least two different growth-rate-determining mechanisms must be involved.

68. Kuleshov, I.M., G.G. Sadikov and Z.A. Sokolov
Neutron diffraction studies of high-temperature beryllium oxides. ZHURNAL FIZICHESKOI KHIMII 36; 1369–1371, June 1962. (In Russian)

Neutron and x-ray diffraction analyses were made of the crystal lattice of beryllium oxide annealed at 2000° C. Neutron diffraction data confirmed x-ray data on the Be atom position in the lattice. Neutron data indicated the magnitude of the temperature constant B = 0.92 and the Debye temperature Θ = 602 ± 13°K .

69. Moore, R. E., J. H. Shaffer and H. F. McDuffie
THE PREPARATION OF HIGH-PURITY BERYLLIUM OXIDE THROUGH ACETYLACETONE-EDTA SOLVENT EXTRACTION PROCESS. Oak Ridge National Laboratory, Tenn. Rept ORNL-3323. 27 Sep 1962. 33p. (Contract W-7405-eng-26)

A solvent extraction process was devised and used successfully in the preparation of high-purity BeO.

70. Sjodahl, L. H. and S. F. Bartram
Grain orientation in extruded BeO. AMERICAN CERAMIC SOCIETY. BULLETIN 11 (9):585, Sep 1962.

An < 001 > texture has been observed in extruded and sintered rods using BeO powder calcined from $BeSO_4$ but not in rods from powder calcined from $Be(OH)_2$ or in isostatically pressed rods of either type. The angular distribution of orientation is measured by x-ray diffraction using reflections from five crystallographic planes in a transverse section. The distribution function so derived is used to interpret anisotropy in thermal expansion, Young's modulus, and radiation-induced swelling.

71. Smith, D. K., C. F. Cline and V. D. Frechette
A high temperature crystallographic phase inversion in BeO. JOURNAL OF NUCLEAR MATERIALS 6(3):265–270, Aug 1962.

The existence of a high-temperature polymorph of BeO has been verified by high-temperature x-ray diffraction methods. The high temperature pattern has been indexed using a cubic cell with $a = 4.76$ Å. The transformation temperature is $2050 \pm 25°C$, and the reaction is rapidly reversible. Optical and x-ray measurements indicate that cycling through the transformation temperature will cause changes in the crystallographic orientations of grains.

72. Stehsel, M. L., R. M. Hale and C. E. Waller
Modulus of rupture measurements on beryllium oxide at elevated temperatures. In MECHANICAL PROPERTIES OF ENGINEERING CERAMICS. PROCEEDINGS CONFERENCE, RALEIGH, N. C., 1960. 1961. p. 225–237.

The modulus of rupture for BeO was measured in a He atmosphere up to 1650° by subjecting test beams to three-point loading in an Instron tensile-testing machine. Comparative data are presented for hot-pressed, cold-pressed, and slip-cast specimens provided by five manufacturers. The hot-pressed specimens are stronger and have the highest modulus of rupture at most temperatures. Maximum strength usually occurred in the specimens, particularly those made by cold pressing and slip casting, at 800 ± 100°. Above 1600° the strength of the cold-pressed and slip-cast specimens rapidly converged toward the same level; while several groups of hot-pressed samples still possessed much higher moduli at this temperature. Two modes of failure were observed. Brittle fracture occurred in all specimens when the modules of rupture was greater than 10,000 lb./sq. in. Below this level, cold-pressed and slip-cast specimens fractured by a stress-relieving phenomenon.

73. Taylor, P. G. and I. J. Holland
Beryllia ceramics. ENGINEERING MATERIALS AND DESIGN 5(9):646–649, Sep 1962.

Introduction of beryllia ceramics and production of material; discussion of its properties and applications emphasizing thermal shock resistance.

POWDER METALLURGY

74. Armed Services Technical Information Agency, Arlington, Va.
BERYLLIA – A REPORT BIBLIOGRAPHY.
Rept. ASTIA ARB No. 10706. Jun 1962. 20p.

A review of literature published between 1957 and June 1962, covering studies made on the hot pressing, analysis, sintering, fabricating and coating of beryllia.

75. Mazza, E.
Hydrostatic-isostatic forming. PRECISION
METAL MOLDING 20(4):38–41, Apr 1962.

Report deals only with beryllium but basic process is adaptable other refractory metals; method now is slow and fairly expensive; much lower scrap losses due to less machining, and superior properties obtained may, however, offset higher forming costs; best hydrostatic pressing conditions under constant isostatic conditions are described; effects of hydrostatic pressure and of isostatic temperature, pressure, and time on physical and mechanical properties of beryllium.

PROCESSING

76. American Society for Metals.
ULTRA-HIGH-PURITY METALS. Metals Park,
Ohio, The Society, 1962. 264p.

Purification, electrorefining and zone melting of ... Be ... and other metals. Influence of impurities on crystal structure, electronic structure, mechanical properties, electrical properties, electromagnetic properties and thermo-electricity.

77. Baker, D. H., Jr. and T. A. Henrie
Electrolytic preparation of pure metals.
In ULTA-HIGH PURITY METALS. Metals
Park, Ohio, American Society for Metals,
1962. p. 36–54.

Electrorefining of Be ... by electrolysis to produce metals of high purity.

78. Boisde, G. et al.
Contribution to the study of the obtainment of high purity beryllium by electrolytic refinement in molten salt baths. (Contribution à l'etude de l'obtention de beryllium de haute purete par electroraffinage en bains de sels fondus)
JOURNAL OF NUCLEAR MATERIALS
6(3):256-264, Aug 1962. (In French)

By electrolytic refining at 400-500° C from molten baths containing a $LiCl$-KCl-$BeCl_2$ mixture, beryllium of high purity can be obtained. A study of this method of purification has permitted the establishment of the following characteristic features: (1) One can use the necessary anhydrous baths by dissolving $BeCl_2$ "in situ": $BeCl_2$ is formed within the molten $LiCl$-KCl solvent itself by the chemical displacement reaction $Be + SnCl_2 \rightarrow BeCl_2 + Sn$. (2) Because impurities (notably iron) are concentrated in the immediate vicinity of the cathode, the technique used for washing the deposits has a pronounced influence on the purity of the refined metal. (3) According to the current density/potential plots, the great efficacy of this method of electrolytic refining appears to be due to a very fast-acting electrochemical system favorable to the elimination of impurities.

79. Crook, R. D., D. Geldart and J. M. Alexander
IMPROVEMENTS IN OR RELATING TO THE PRODUCTION OF BERYLLIUM METAL. (Assigned to United Kingdom Atomic Energy Authority, London, England). British Patent 900,698.
11 Jul 1962.

A process is given for producing Be metal from $Be(OH)_2$. The process comprises converting the hydroxide into oxide briquettes, chlorinating the briquettes, and passing the $BeCl_2$ vapor through a packed column in contact with a depleted $BeCl_2$-$NaCl$ melt from an electrolysis stage, where by the deplated melt become enriched in $BeCl_2$ and may be returned to the electrolysis stage for Be production. Equipment for the process is described.

80. Gasc, C. and M. Baudeau
On different processes of recrystallization in beryllium. JOURNAL OF NUCLEAR MATERIALS 6:120–122, May–Jun 1962. (In French)

A brief resume is given of results obtained on the recrystallization of Be. The metal was worked by cutting and by compression at 400° C. A microscopic study showed four processes permitting the metal to lose its worked structure: induced growth, classic germination, polygonization, and germination from twins.

81. Grala, E. M., et al.
ROLLING IMPROVED BERYLLIUM SHEET. PHASE I. TECHNOLOGY INVESTIGATION AND EXPERIMENTAL ROLLING. Brush Beryllium Co., Cleveland, Ohio. Rept for 5 Jul 1961–4 Feb 1962. Technical rept. no. 269-234. Jul 1962. 87p. (Contract AF 33(600)43037) ASTIA AD-283 406.

The presence of systematic differences in beryllium sheet was revealed by an analysis of variance of commercial sheet. A process control and reproducibility study showed that these differences in beryllium sheet are caused by systematic differences between and within hot-pressed billets used for rolling slabs. The rolling process was found to be under control. Causes of variation in tensile elongation were found operative within small volumes of single sheet. Breakdown and finish rolling in the temperature range 1800-1600° F produced a coarse grain size and very low tensile elongation. Reduction ratio had a large effect on the third dimension plastic strain of cross rolled beryllium sheet. Finishing operations such as creep flattening, roller leveling, and roll replanishing were investigated, and the effect of these operations on the flatness and tensile properties of beryllium sheet is reported. The effect of various pickling solutions on the bend and tensile properties of beryllium was also studied.

82. Gross, A. G., Jr. and R. G. O'Rourke
DEVELOPMENT OF FINE DIAMETER HIGH-PURITY WIRE FROM ZONE-REFINED BERYLLIUM. Brush Beryllium Co., Cleveland, Ohio. Progress rept. no. 2, 1 Jun–1 Aug 1962. Technical rept. no. 276-236. 1 Aug 1962. 15p. (Contract NOw 62-0067-c) ASTIA AD-283 080.

Efforts continued on the fabrication of wire from single crystals of zone-refined Be. Swaging and wire-drawing results are presented. The primary cause of fracture during wire drawing is believed to be the stringers of nonmetallic inclusions which are consistently present in the zone-refined beryllium. The interpretation of the results of the tensile testing of A. 11 at 0.027-in. diam. was shown to be valid. It was shown that the swaging and wire-drawing operations do not contaminate chemically the zone-refined Be.

83. Less common metals and modern chemical processing. I&EC/INDUSTRIAL AND ENGINEERING CHEMISTRY 54(9):57–60, Sep 1962.

Bibliographic survey of high and low temperature mechanical tests and of shaping, joining and coating technique studies for Be ...

84. May, J. T. and C. L. Hoatson
STUDIES OF ANHYDROUS METHODS FOR EXTRACTING BERYLLIUM FROM LOW-GRADE ORES. Bureau of Mines. Report of Investigations No. 6037. 1962. 19p.

Beryl, helvite, and phenacite materials containing from 0.1 to 2.8% BeO were treated by direct fluorination and carbide-clorination; treatment of concentrate-carbon mixtures with anhydrous hydrogen fluoride extracted 99% of beryllium in concentrate; soluble fluoride product, converted to oxide, contained 70% BeO; chlorination of beryllium-silicon carbide, extracted beryllium into volatile chloride product.

85. Pohodin-Alexeen, H. I., V. M. Havrilon,
and F. V. Korolev
Using low-frequency vibrations during continuous casting of beryllium bronze. TSVETNYE METALLY (4):69–73, 1962. (In Russian)

Continuous casting of induction melted BrB-2.5 and BNT bronze using graphite crucibles and eccentric vibrators during melt crystallization using excentric vibrators. Determination of the ingot structure, and effect of the fibration amplitude and frequency on hardness, brittleness and microstructure.

86. Sherwood, E. M.
Less common metals and modern chemical processing. INDUSTRIAL AND ENGINEERING CHEMISTRY 54(9):57–61, Sep 1962.

A review is given on the properties and chemical processing methods for Be ... Protective coatings are also discussed.

87. Weismantel, E. E. and K. C. Taber
DEVELOPMENT OF TECHNIQUES FOR PRODUCING BERYLLIUM STRUCTURAL SHAPES. Beryllium Corp., Reading, Pa.
Final technical engineering rept, 24 Aug 1960–8 Mar 1962. 8 Apr 1962. 126p. (Contract AF 33(600)41959) (ASD TR 62-7-828)
ASTIA AD-283 699.

A manufacturing process was developed demonstrating the feasibility of forming structural configurations from high strength beryllium sheet and extruded preforms. The structural shapes were investigated in short sections only. The program was terminated when the feasibility of the various processes was determined. Angle, channel and zee sections were successfully formed from cross-rolled sheet. Rod, bar and tee sections were produced by a combination of extrusion and rolling. The beryllium sheet forming included investigation of roll forming, brake forming, and heat setting. Rod, bar, and tee sections were formed by rolling extruded pre-forms and by a composite billet process. Considerable effort was devoted to the development

of sheet rolling parameters to obtain consistent cross-rolled sheet of 55,000 psi yield strength and 75,000 tensile strength. The combined extrusion and rolling methods for rod, bar, and tee sections can also be employed for other structural configurations and is shown to have potential for developing substantially higher strength levels than heretofore achieved, while retaining higher elongation.

88. Zefirov, A. P. and A. A. Lanin
Production and utilization of beryllium. In
METALLUR GY AND METALLOGRAPHY OF
PURE METALS. V. S. Yemel'Yanov and
A. I. Yevstyukhin, eds. N. Y., Gordon and
Breach, Science Publishers, Inc., 1962.
p. 327–340.

Benefication of beryllium ores, processing concentrates, production of beryllium oxides, methods of producing and refining beryllium metals. Influence of berullium additions on mechanical and physical properties and corrosion resistance of Cu, Al, Zn, and Fe base alloys. Use of beryllium and its compounds in nuclear engineering.

PROPERTIES

89. Amonenko, V. M. et al.
Solubility of admixtures in beryllium.
FIZIKA METALLOV I METALLOVEDENIE
14(1):128–129, 1962. (In Russian)

Determination of C, N and O solubility in pure Be at 1200° C by the temperature dependence of the lattice parameters and expansion coefficient.

90. Armed Services Technical Information Agency,
Arlington, Va.
GRAIN REFINEMENT IN REFRACTORY METALS –
A REPORT BIBLIOGRAPHY. Rept. ASTIA ARB
No. 10653. Jun 1962. 17p.

A review of literature published from 1957 to June 1962 covering electron beam melting, arc casting, heat treating, grain refinement, forging and rolling of ... beryllium ... and its alloys.

91. Bonfield, W., J. A. Sartell, and C. H. Li
Effect of surface condition on the microstrain of beryllium. JOURNAL OF METALS 14(9):695, Sep 1962.

The stress to cause a permanent microstrain of 2×10^{-6} in. per in. (defined as the microscopic yield stress) in beryllium is found to be very sensitive to surface condition. The initiation of plastic flow in as-machined specimens, which contain a high density of twins and large residual compressive stresses to a depth of about 0.010 in. from the surface, occurs by the nucleation of slip from high stress fields around twin tips in the surface layers. Removal of the damaged surface layers by chemical polishing results in an appreciable increase in the microscopic yield stress, which is attributed to the removal of stress raising twins rather than to the release of residual stresses. Electron microscope studies indicate that the considerable stress to initiate dislocation motion, and the subsequent rapid strain hardening, are due to the high density and tangled nature of the dislocations produced by hot pressing.

92. Bunshah, R. F.
A FRESH LOOK AT THE PROBLEMS IN BERYLLIUM METALLURGY. California Univ., Lawrence Radiation Laboratory, Livermore. Report UCRL-6410. 31 Mar 1961. 21p. (Contract W-7405-eng-48)

The current status of beryllium metallurgy is reviewed. The nonsystematic variation in the mechanical properties, particularly the low room temperature and the ductility minimum around 600°C, are its most disturbing features. Recent work shows that the 600°C ductility minimum can be eliminated by overaging of controlled compositions, which means that commercial beryllium may be considered as a complex, unstable age-hardening alloy rather than as a somewhat impure dilute alloy. The implications of this on the room temperature properties are discussed. Some comments on the technological problems and analytical requirements are made.

93. Damiano, V. V.
Direct observations of etch pits at dislocations in beryllium. In ELECTRON MICROSCOPY; FIFTH INTERNATIONAL CONGRESS FOR ELECTRON MICROSCOPY HELD IN PHILADELPHIA, PENNSYLVANIA, AUGUST 29TH TO SEPTEMBER 5TH 1962. VOLUME I. NON-BIOLOGY. S. S. Breese, ed. New York, Academic Press, 1962. p. B-6.

The beryllium crystal used in this experiment was deformed on the order of 10% strain by compression at room temperature. The compression surfaces were then electrolytically polished, and etch pits were produced by sudden and brief increases in the current density. Foils were prepared from the crystal. After numerous attempts, a specimen was found which revealed both dislocations in contrast and etch pits. Numerous etch pits were examined, and in every case one or more dislocations were found to be associated with the etch pits. The density of etch pits was an order of magnitude lower than the density of dislocations observed, since junctions of dislocations rather than single dislocations appeared to be preferred etching sites.

94. Gelles, S. H.
BERYLLIUM RESEARCH AND DEVELOPMENT PROGRAM. Nuclear Metals, Inc., Concord, Mass. Quarterly progress rept., 1 Apr – 30 Jun 1962. Rept. NMI-9522. 5 Nov 1962. 82p. (Contract Af 33(616)-7065) NASA N63-10311.

Beryllium research continues in the following areas: brittle behavior by means of transmission electron microscopy; ductile-brittle transition; recrystallization and grain growth; identification of impurities and precipitates; and fabrication of fine-grained beryllium from ultrafine powders.

95. Gelles, S. H.
BERYLLIUM RESEARCH AND DEVELOPMENT PROGRAM. Nuclear Metals, Inc., Concord, Mass. Quarterly progress rept. on Aeronautical Systems Division, 1 Jan 1962–31 Mar 1962. Report NMI-9519. 25 Jun 1962. 37p. (Contract AF 33(616)-7065).

Progress on the beryllium research program is reported. Brittle behavior, metallurgical factors affecting ductile-brittle transition, preparation of ultra-fine powder, preparation and evaluation of fine-grained recrystallization and grain growth, identification of impurities, preparation of high-purity metal and fabrication from ultra-fine powders is being studied.

96. Gelles, S. H.
BERYLLIUM RESEARCH AND DEVELOPMENT PROGRAM. Nuclear Metals, Inc., Concord, Mass. Quarterly progress rept. to Aeronautical Systems Division, 1 Oct 1961–31 Dec 1961. Report NMI-9517. 16 Apr 1962. 30p. (Contract AF 33(616)-7065).

Plans for a Be research and development program are described. Work being conducted on brittleness in Be is detailed as well as work in progress on the production and evaluation of high purity Be.

97. Grala, E. M. et al.
ROLLING IMPROVED BERYLLIUM SHEET. PHASE II. Brush Beryllium Co., Cleveland, Ohio. Interim rept. 26 Mar–25 May 1962 on Isotropic Ductility. Technical rept. no. 279-234. Aug 1962. 33p. (Contract AF 33(600)43037, Proj. 7-753) ASTIA AD-285 174.

The effect of heat treating at three temperature levels, 1750, 1920, and 2020°F, and three time levels, 6, 60, and 600 minutes, on the tensile properties and third

dimension plastic strain of cross-rolled beryllium sheet was investigated. Differences between the nine different heat treatments were shown to be statistically significant and with a different pattern of effects for the different properties. The average effect of these treatments was to reduce the ultimate strength from 78,400 to 58,400 psi, the yield strength from 60,700 to 32,700 psi, and the elongation from 15.5 to 8.1%. The response of the third dimension plastic strain to these same treatments was to increase the average value from 0.58 to 0.77%.

98. Jacobson, M. I., F. M. Almeter and E. C. Burke
Surface damage in beryllium. AMERICAN SOCIETY FOR METALS. TRANSACTION. QUARTERLY 55:492-504, 1962.

Hot-pressed, hot-rolled, and hot-upset Be sheets were studied. Metallographic examination shows twins and cracks. Tensile, bend and impact tests showed that annealing removed twins, relieved residual stresses, and increased ductility. Electron diffraction showed a thin layer of basal planes oriented paralled to the surface of ground specimens. Poor ductility in machined areas results from highly twinned areas which act as locations for crack formation. Twins are more detrimental than cracks.

99. Kaufmann, A. R.
FUNDAMENTAL AND APPLIED RESEARCH AND DEVELOPMENT IN METALLURGY. Nuclear Metals, Inc., Concord, Mass. Progress rept. to U. S. Atomic Energy Commission, May 1962. Rept. NMI-2107. 31 Jul 1962. 26p. (Contract AT(30-1)2784). (Available from Office of Technical Services, Washington 25, D. C.) NASA N62-17562.

... In evaluating zone-refined beryllium, crystals of different purity levels were stressed in tension at room temperature. Results showed that for high-purity crystals, the critical resolved shear stress for prismatic slip actually has a greater purity dependence than does the critical resolved shear stress for basal slip; the data also indicated that the temperature dependence of the yield stress is increased by purification.

100. Krusos, J. N. et al.
SHEET BERYLLIUM COMPOSITE STRUCTURES.
Aeronca Manufacturing Corp., Middletown, Ohio.
Interim technical documentary progress rept. no. 4,
1 Jul 1962—30 Sep 1962. Oct 1962. 145p. (Contract
AF33(657)-7151) (ASD-TR-7-845(IV)).

This program is directed toward the design, development of manufacturing processes, testing, and evaluation of reinforced ceramic heat shields combined with load bearing honeycomb panel structure. The composite structure will be capable of withstanding surface temperatures in excess of 3000° for one hour. The loading bearing semi-monocoque structure will operate in termperature ranges suitable for beryllium, stainless steels, and super alloys. A ninety-inch section of a typical lifting body re-entry vehicle will be fabricated for test under a stimulated super-orbital re-entry environment. Work has been performed in the definition of environment, design analysis, materials selection, and component testing. The program was redirected to meet super-orbital mission loads as the design objective. The design surface temperature of the forebody structure during re-entry is retained at 3400°F, and an ablative coating is contemplated to resist extreme heat rates which occur briefly during the super-orbital re-entry phase. Ablative development is not part of this program. Materials selection for the structural portions include A-286 and Hastealloy C honeycomb, and A-286 and beryllium facing sheets. Development work has been completed on forming and brazing techniques. Material Selections for the heat shield have been completed and include alumina foam with a zirconia coating. Further tests have been performed to define and develop design limits of this material. Environmental tests of large composite panels in ram-jet exhaust and propane hot gas facilities demonstrated good heat shield, joint, and coating performance under conditions of high pressure, noise, and temperature.

101. Lieberman, D. S.
CONFERENCE ON THE METALLURGY OF
BERYLLIUM. Office of Naval Research,
London. Technical rept. no. ORNL-C-18-62.
27 Jul 1962. 32p. ASTIA AD-285 399.

Contents: Beryllium (Mechanical and physical properties; deformation and fracture studies; elevated temperature ductility; ductile/brittle transition temperature); beryllium in reactors (corrosion and compatibility; irradiation properties; metallurgical considerations); beryllium in aircraft; metal preparation and fabrication (pure metal preparation; beryllium-base alloys; diagnostic techniques; ingot and powder; rolling and extrusion).

102. Lindsay, H. M. and A. Moore
A METALLOGRAPHIC STUDY OF THE AGEING CHARACTERISTICS OF BERYLLIUM-IRON ALLOYS, BETWEEN 400°C AND 1050°C.
United Kingdom Atomic Energy Authority. Weapons Group. Atomic Weapons Research Establishment, Aldermaston, Berkshire, England. Rept. AWRE-0-48/62. Aug 1962. 30p.

The ageing characteristics of Be-Fe alloys containing 0.03 to 0.4 wt % Fe were determined by tensile testing at 600°C. Specimens from cast-and-extruded alloys were examined in the as extruded and aged conditions and also after cycling between the solution treated and aged conditions. There was agreement between the metallographic observations and the corresponding ranges for solution treatment and ageing, as defined from echanical properties. It was concluded, however, that is no case is a single phase solid solution retained on quenching to 20°C. Generally, ageing at temperatures of 100 to 200°C below the solution treatment zone led to precipitation primarily on a network 5 to 10μ wide, adjacent to the grain boundaries, and to a lesser degree within the matrix. By contrast, ageing at higher temperatures led to an increase in precipitation at grain boundaries, and the development of a denuded zone 5μ wide adjacent to the grain boundaries.

103. Lippart, T. E. and J. R. Lewis
Beryllides – a discussion and rebuttal.
JOURNAL OF METALS 14(8):568–569, Aug 1962.

Critical evaluation of beryllium in terms of oxidation resistance, thermal shock and stress resistance and low temperature instability.

104. Marco, I. A. D. and T. P. Bradley
MECHANICAL PROPERTIES AND
FORMABILITY OF BERYLLIUM SHEET.
McDonnell Aircraft Corp., St. Louis, Mo.
Final rept. Rept. 9091. 10 Oct 1962. 39p.
(Contract AF33(657)).

Two sheets of beryllium produced under an AMC sponsored development program were submitted to MAC for mechanical property and bend test evaluation. Tests were conducted to determine the room and elevated temperature mechanical properties and the elevated temperature bending characteristics of the beryllium sheets. The effects of annealing on mechanical properties, and the effect of chemically polishing the specimens in the reduced section were evaluated. The bend test results were inconclusive; however, crack-free specimens were produced when specimens were tested at temperatures of 1000 and 1200°F and bent over die radii of 0.500 and 0.375 inch, respectively. Chemically polishing the reduced section appears to improve values of Ftu and per cent elongation.

105. National Research Council, Materials Board, C
Washington, D. C.
REPORT OF BERYLLIUM COMMITEEE (U).
Rept. no. MAB-185-M. Aug 1962. 100p.
(Contract SD-118) ASTIA AD-331 804.
CONFIDENTIAL REPORT

106. Nuclear Metals, Inc., Concord, Mass.
FUNDAMENTAL AND APPLIED RESEARCH
AND DEVELOPMENT IN METALLURGY.
Progress rept. to United States Atomic Energy
Commission. Apr 1962. Rept. NMI-2106.
23 Jul 1962. 18p. (Contract AT(30-1)-2784).

Activities in an investigation of refractory metal alloys aimed at relating their high-temperature properties to features of their phase diagrams, microstructures, and thermal histories are reported. Selected compositions from binary systems containing HF, Os, Re, and Ru are being investigated. During the report period, ingots of unalloyed Nb, unalloyed Ta, Mo-10 at. % Hf, and W-5 at. % Ru were prepared and

extruded. A summary of extrusion data is included. The unalloyed Nb and Ta extruded at 1850°, and extrustions of Mo-10, at. & Hf were successful at 2000°. Extrusions of the W-5 at. % Ru failed to produce material for mechanical testing. The extruded refractory materials were evaluated by tensile tests at 1200, 1400, and 1600°C and hot hardness measurements at 300, 500, and 800°C.

107. Smith, R. L. and A. A. Hendrickson
Mechanical properties of high-purity metals.
In ULTRA-HIGH-PURITY METALS. Metals
Park, Ohio, American Society for Metals, 1962.
p. 85 – 114.

Determination of tensile strength, yield strength, ductility and shear stress of high purity ... Be as influenced by impurities, grain size, structural perfection, strain rate and temperature.

108. Spangler, G. E., M. W. Herman and E. J. Arndt
PREPARATION AND EVALUATION OF HIGH-PURITY BERYLLIUM. Franklin Institute,
Philadelphia, Pa. Rept F-A 2476. 1961. 59p.

Single crystals were prepared by the floating-zone refining method and tested in tension with orientation yielding basal-plane slip. Critical resolved shear stress varied between 400 and 2400 lb/in according to purity with corresponding 220-16% strain. Results of working and recrystallization studies are given.

109. Sujata, H. L., M. King and F. J. Waters
THERMAL STRESS TESTING OF BERYLLIUM OXIDE MODERATOR SHAPES. Atomics International. Division of North American Aviation,
Inc., Canoga Park, Calif. Rept. NAA-SR-6504.
1 Aug 1962. 84p. (Contract AT(11-1)-Gen-8).

Performated BeO plates were thermal shock tested to evaluate the effect of: localized temperature variations adjacent to the perforations, and radial gradients across the entire plate. For localized temperature variations, the plates were subjected to a

1350°F thermal shock from 2400°F; the radial gradient effects were evaluated by an air quench from 1900°F. Measured temperatures were in good agreement with theoretical values. Thermal stress level and distribution were evaluated and compared with measured modulus of rupture values to interpret the degree of cracking and crazing, and the agreement was good. Several plates were cycled with radial temperature gradients, and the development and propagation of cracks was noted. Evidence is presented which shows that BeO plates, subjected to high thermal stresses, crack and craze but still remain functionally useful.

110. Taylor, W. and A. Moore
TENSILE FRACTURE CHARACTERISTICS OF EXTRUDED INGOT BERYLLIUM AND BERYLLIUM-IRON ALLOYS. United Kingdom Atomic Energy Authority. Weapons Group. Atomic Weapons Research Establishment, Aldermaston, Berkshire, England. Rept. AWRE-0-42/62. Aug 1962. 24p.

Tensile tests were carried out between 20 and 600°C on three extruded ingot beryllium-iron alloys, having iron contents within the range 0.024 wt % Fe−0.40 wt % Fe. The materials were tested both in the as-extruded condition, and after heat treatments designed to overage the metal with respect to its iron content. Tests were performed on transverse, as well as longitudinal specimens, with respect to the extrusion axis, in order to obtain an indication of the influence of texture variation upon the tensile behavior. Deformation and fracture types produced in the tests were studied and related to the testing temperature, purity, thermal history and mechanical properties of the specimen. The observations are briefly discussed in the light of current knowledge and theory pertaining to the deformation behavior of beryllium.

111. Taylor, W. and A. Moore
TENSILE FRACTURE CHARACTERISTICS OF EXTRUDED INGOT BERYLLIUM AND BERYLLIUM-IRON ALLOYS. United Kingdom Atomic Energy Authority. Atomic Research Weapons Establishment. Aldermaston, Berkshire, England. Rept. 0-42/62. 1962. 22p.

Three extruded ingots of Be containing Fe in concentrations of 0.024-0.40 were subjected to tensile tests at temperatures between 20 and 600°. Brittle trans-crystalline failure within the range 20-200° is probably initiated by the Stroh split

bend plane mechanism and is unaffected by over-aging anneals. Between 200 and 400°, other deformation modes become operative while the temperature is not high enough to cause precipitation hardening. These modes may include grain boundary sliding. Between 400 and 600°, grain boundary failure becomes more important, leading to a decrease in ductility. Suitable over-aging anneals replace this intergranular fracture by a fibrous mixture of transcrystalline and boundary fracture, resulting in increased elongation values. Twinning does not make an important contribution to tensile deformation in the alloys considered.

112. Verkin, B. I., I. M. Dmitrenko, and I. V. Svechkarev
Magnetic properties of beryllium at temperatures from 300 to 4.2°K. ZHURNAL EKSPERIMENTAL' NOI I TEORETICHESKOI FIZIKI 40(2):670–671, 1961. (In Russian)

The measurements were carried out using Faraday's method with a vertical gradient in fields up to 10k oersted. A balance on bracings with photoelectric compensation was used. The angular dependences of the magnetic susceptibility x of 2 ~ 99.9% pure specimens and 2 In specimens were determined in a temperature region 300-4.2°K. It was found that the angular dependences of x in Be (above 20°K) and In are described by the cosine law. The dependence of the main values of x on temperature is characteristic for small electronic groups. It was found that x of In is very sensitive to impurities.

113. Weismantel, E. E. and H. L. Black
The effect of rolling parameters on the properties of beryllium sheet metal. AMERICAN SOCIETY FOR METALS. TRANSACTIONS QUARTERLY 55:685–696, 1962.

A study of breakdown temperature, final rolling temperature, and reduction ratio with Be sheet alloys containing 98.28 and 97.68% Be and 1.25 and 1.85% BeO, respectively, showed that lower rolling temperatures produced highest tensile strength, highest ductility, and finer grain structure. Slightly higher strengths were developed in the alloy containing the larger amount of BeO.

114. What is beryllium?
TECHNIK UND BETRIEB 14(8):124–125,
Aug 1962. (In German)

Review of the physical, chemical and metallurgical properties of the metal beryllium, with emphasis on scaling resistance, deoxidizing and desulphurizing characteristics, alloying properties in copper alloys with particular reference to 2% beryllium bronze, and nuclear applications as in moderators and neutron sources.

115. Wolff, A. K., S. H. Gelles, and L. R. Aronin
IMPURITY EFFECTS IN COMMERCIALLY
PURE BERYLLIUM PREPARED FROM POWDER.
Nuclear Metals, Inc., Concord, Mass. Rept.
NMI-TJ-40 (Rev.) 1961. 25p. (Contracts
AT(30-1)-1565 and AF33(616)-7065).

An investigation was conducted to determine the role of impurities in commercial beryllium prepared from powders. It was found that room temperature tensile properties of beryllium can be altered by aging treatments. Ultimate strengths were found to vary from 52000 to 95000 psi and ductilities varied from less than 1 to 14%. No significant changes in yield strength were observed. Subsequent studies showed that no textural changes occurred during aging, and the tensile property variations were attributed to precipitation phenomena. A yield point, absent in the as-solution-treated material, was observed to occur after aging at 400°C, but the occurrence of the yield point appeared to be sensitive to minor variations introduced in the processing, presumably variations in grain size. Limited high temperature tensile data showed that properties between room temperature and 400°C increased with decreasing cooling rate from the solutionizing temperature. Repeated yielding was observed for tests at 400 but not 600°C. X-ray diffractometer studies showed the growth, after aging, of precipitate peaks which were not present in the as-solution-treated stage. The precipitate was identified as a face-centered-cubic structure with a lattice constant of 6.07Å and having a preferred orientation with respect to the beryllium matrix. Electron microbeam probe studies indicated that iron segregated to the grain boundaries during aging. Aluminum and silicon were found to be segregated at grain boundaries even in the solution treated case. Strain-aging studies showed that a yield point induced by aging and eliminated by straining could be recovered by subsequent aging. An activation energy for return of the yield point was determined to be 48000 cal/g mole which compared favorably with the activation energies for diffusion of iron and nickel in beryllium. The observed strain-aging phenomena were consistent with the Cottrell theory of dislocation-locking by impurity atmospheres.

116. Tariff Commission, Washington, D. C.
BERYLLIUM, REPORT TO CONGRESS ON INVESTIGATION NO. 332-41 UNDER SEC. 332 OF TARIFF ACT OF 1930, MADE PURSUANT TO SENATE RESOLUTION 206, 87TH CONGRESS, ADOPTED SEPT. 23, 1961. TC Publication 66.
Aug 1962. 72p.

This report presents information on U. S. production consumption, imports, exports, and foreign production, and other data pertinent to an understanding of the conditions of competition between domestically produced and imported beryllium ores and refined beryllium products. Tables are included covering: (1) selected physical properties of beryllium and several competing metals; (2) principal beryllium minerals; (3) rates of duty; (4) shipments or ore; (5) range in price quotations for specified beryllium products; and (6) world production, by country.

AUTHOR INDEX